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Forest Service

Forestry Research West

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A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

Forestry Research West

In This Issue

Cover

Even decades ago, resource specialists were concerned about deteriorating rangeland conditions in the southwest. This 1916 photo shows a study underway on the Jornada Experimental Range in southern New Mexico. Today, many ranges in this region continue to be overgrazed and remain in poor condition. Scientists at the Rocky Mountain Station have developed a guidebook to help ranchers and land managers estimate livestock carrying capacities for these fragile grasslands. Details begin on page 17.

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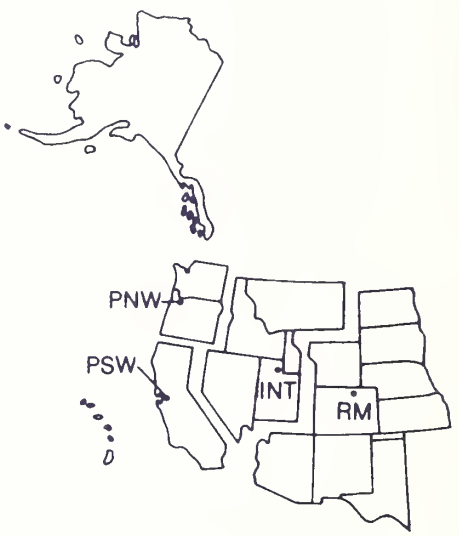


Alarming *Armillaria*: a problem in the Inland West

by Elizabeth Close
Intermountain Station

Casual visitors to the woods are usually focused on the tree canopy overhead—few of them think about the forest teeming under their tennis shoes. But resource managers recognize the soil as a lively and important part of the forest ecosystem. They know the soil is not only important, but critical in determining what vegetation any site supports. And the soil most attracts their attention when a site goes "bad"—when a once highly productive site slips to one yielding only a marginal crop of trees.

Researchers at the Intermountain Research Station's Forestry Sciences Laboratory in Moscow, Idaho are "digging in the dirt" to learn more about the relationship of forest soil to forest productivity. Since the early 1980's, a project headed by Plant Pathologist Al Harvey has learned much about soil components and inhabitants, and about how forest management practices can help or harm future soil site productivity. The project's research emphasizes the importance of organic materials—decaying plant debris and woody residues—as soil components supplying storehouses of nutrients and moisture for new plant growth. Organic materials also provide environment and energy for many microorganisms critical to both the nutritional quality of forest soils, and the ability of some trees to extract nutrients and moisture from the soil.

Plant Pathologist Neil Martin examines Armillaria *fruiting bodies in the forest.*

An example of important and beneficial soil microorganisms is wood decay fungi, which help to sustain certain conifer rooting, nitrogen input, nutrient storage, and recycling capabilities. But other soil inhabitants can be a bit overzealous in the drive to break down and recycle organic material. *Armillaria* spp., or shoestring root rot fungus, has the capability to "recycle"—that is, "kill"—the root systems of living trees. And once a tree's roots are gone, it soon starves, falling to the ground where other soil-bound nutrient recyclers feast on the now reachable wood fiber.

A world-wide problem

"*Armillaria*, in some form or another, occurs world-wide," says Harvey. "It has a broad host range, and affects a large percentage of the world's woody plants. We will never get rid of it, but we don't really want to. *Armillaria* is as much a part of the natural forest ecosystem as trees, often existing peaceably and causing no harm. But when it gets "turned on," in a pathogenic sense, it can damage an existing stand and stay in the soil to inhibit following generations."

Harvey stresses the seriousness of the Inland West's root rot problem, "What we have in northern Idaho is a full-blown epidemic. *Armillaria* infection is on the rise, and causing extensive damage—estimates of 50 percent loss of site productivity may be conservative in some areas. There is potential to lose even more. This may seem like a pessimistic view, but where do you draw the line between pessimism and realism—you can't realistically ignore this problem and have it go away."

"*Armillaria* is a very effective nutrient recycler. We just need to keep it from recycling things that we don't want recycled yet—like the roots of living trees."

So what causes *Armillaria* to get pathogenically "turned on"? The project's scientists are investigating a web of relationships between host, pathogen, and environment that seems, at times, to uncover as many questions as answers. In the "outdoor lab" of the Inland West, they are well situated to work at untangling that web.

The outdoor lab

The Inland West represents an extended edge between the crest of the Cascades to the west, and the crest of the Rockies to the east. "What we have is a coast-type forest in a more continental climate," Harvey said. "Ecosystems to the west are better buffered, with more moderate climate and better quality soils. When species like grand fjr, Douglas-fir and western hemlock grow in the Inland West, they are pushed to the limits of their range, and lack the built-in resistance they seem to exhibit in western Oregon and Washington. And, while resource managers like to have these species—they regenerate well and can have high market value—their susceptibility to *Armillaria* in this region often makes them chancy choices."

Armillaria *fruiting bodies—outward signs of the underground threat to woody plants.*

Project scientists have shown pine and larch to be more root rot-tolerant. "But we really don't know why *Armillaria* hits some species harder than others," said Harvey, "or why it infects individual trees in a stand, leaving others of the same species untouched. We have found a connection between the condition of a stand, its habitat type, and its susceptibility to root rot attack—when trees get sick, *Armillaria* often moves in. It is definitely a problem of stressed trees and poor sites."

Forester Jonalea Tonn is working on uncovering interactions between growth of certain white pines and susceptibility to *Armillaria* damage. "We need to be able to define a 'poor site,' and it may not only be in terms of productivity," she said. "We need to grow forests that are more healthy, and find ways to block *Armillaria*'s path. And, since *Armillaria*'s path is through the soil, we can go a long way toward properly managing root rot by properly managing soil."

Armillaria's pathogenic path is aided by activities that cause change. For example, it is often given a boost when trees are harvested. After the stems are removed, *Armillaria* seizes the chance to occupy tree roots left in the soil. When regeneration is attempted, the pathogen transfers onto the roots of the seedlings.

According to Harvey, areas with historic patterns of disturbance show an increased rate of attack. "We have sites in northern Idaho, for example, on the Idaho Panhandle National Forests' Fernan Ranger District around Coeur d'Alene, where productive but marginal soils have been logged for over 100 years, he said. "Logging practices typically took the 'biggest and the best', depleting stands of their stronger, more tolerant trees, and extensively disturbing the soil. Now the *Armillaria* has such a strong hold that it is difficult to get susceptible trees to mature there."

The root rot capital

Wes Kellie, Forest Silviculturist for the Idaho Panhandle National Forests, smiles when asked about the designation of the Fernan Ranger District as, "the root rot capital of the world." "Yes, I've heard it called that," he admits, "but we're aggressively working to change that title. We now know that we created a bad situation in the 1970's, when we used partial cut systems rather extensively to replace clearcutting. Partial cutting strategies on the Fernan District resulted in big problems—*Armillaria* stayed with or moved into the trees that were left and spread to the young trees that were planted. Now on sites with major root rot problems, we'll most likely clearcut, prescribe burn and plant more *Armillaria*-tolerant species."

The relationship of *Armillaria* to fire is also under scrutiny. Fire histories show that cyclic fire was a natural feature in northern Idaho forests. After a moderate buildup of fuels, fire would move through an area at temperatures that did minimal soil damage. But since forest management introduced fire control, these areas burn less frequently, creating a greater buildup of fuels. Now when these sites do burn, they burn with much higher temperatures that cause greater degradation of the soil. Fire suppression can also retard nutrient recycling and increase stocking densities, improving conditions for root rot outbreaks.

Armillaria's relationship to other forest pests may also uncover clues to its habits and control. Scientists have noticed some coincidence of the pathogenic fungus with bark beetle infestations, but the relationship is not well established. It may be that both pests pick on the same unthrifty trees for the same reasons, or that site conditions are simultaneously attractive to both. But another microbial organism may have a helpful role as a biological control agent. *Trichoderma*, or sugar fungus, is a general soil inhabitant that also does well after fire, as germination of its spores is stimulated by heat and smoke. *Trichoderma* competes with *Armillaria* by capturing the substrate that *Armillaria* typically occupies, causing it to cease or reduce its production of inoculum.

Extending the models

Involvement with the root rot problem has extended to other Intermountain Research Station projects and to several other research projects throughout the West. A recent meeting of Intermountain Station scientists laid the foundation for a coordinated, Station-wide *Armillaria* research program. And a West-wide root rot model, which simulates the action of *Armillaria* in a stand, has been developed as an extension of the Prognosis Model for Stand Development (see *Forestry Research West*, August 1987). The root rot extension was developed with the cooperation of specialists from universities, Forest Service research, National Forest timber and forest pest management groups, and the British Columbia Forest Service. All these participants supplied the information and/or inventory linkages needed to base the model on actual conditions.

Surrounded by petri dishes, Plant Pathologist Gerald McDonals shows the growth of Armillaria *isolates.*

Incompatible and compatible parings of single basidiospore isolates of Armillaria *spp.*

"We linked the inventory of root-diseased stands to a proposed forest inventory system," said Mensurationist and Prognosis Project Leader Al Stage. "From an inventory of infected trees, we can use the pathologists' knowledge of how root rot works to predict infection of trees nearby. The model incorporates the tolerance of the species, site conditions, and other factors. But the model works as if *Armillaria* spreads, when instead what may be occurring is an ever-present form turning pathogenic. We really aren't sure how it happens. But in the meantime, the model works—it seems to represent the way *Armillaria* damage occurs. It may be right for the wrong reasons."

Harvey stresses that one benefit of the model was getting key people together to participate in its development. "We had to deal with two major opinions of how the fungus behaves," he said. "But working together, we designed the model so it can accommodate both."

"We can use the model to predict the probability of infection and the eventual time of death, as well as what will happen with different stand treatments," Harvey said. "We can better identify areas that are getting into trouble before the major losses of productivity to *Armillaria* occur."

Other models, developed at the University of Montana and the Intermountain Research Station's Intermountain Fire Sciences Laboratory in Missoula, are being adapted for use in *Armillaria* research. MT-CLIM provides daily microclimate conditions to a physiological process model called DAYTRANS, and to a nutrient recycling model called FORTNITE which keeps track of nitrogen. "With this combination we can more truly emulate how trees grow under different conditions," said Plant Pathologist Geral McDonald. "We can look at a number of physiological traits that will help assess stand health, and develop the characteristics of a more resistant population. Maybe the health of the stand instead of the genetic makeup is the most important feature in root rot resistance."

"We're just now realizing the potential damage *Armillaria* can cause," McDonald said. "because we thought we knew more about it that we do. We need to frame our knowledge of ecosystem patterns and responses with broad-based ecological and physiological process models. What we're learning can be extended through models, as we influence the models to influence management."

The study of host-pathogen-environment relationships will yield many methods for decreasing the loss of forest productivity to *Armillaria* in the Inland West. But another major part of the research project is devoted to studying the characteristics of the microbial organism itself. Plant Pathologist Geral McDonald also concentrates on that.

Sorting out the species

"The taxonomy of *Armillaria* as an organism is not well known," said McDonald. "It was as recently as the late 1970's that the fungus was thought to be a single species instead of a large collection of species. Nine species have been identified in North America, but there is some dispute among 'armillariologists' about the classification. We have isolated four species here in the Inland West, and believe two of these are causing most of the damage, but there may be massive amounts of variation even within these species. We don't know if the species segregate by host, or why some hosts are more tolerant than others. And do *Armillaria* species get "turned on" in different ways? Do conditions at the time of site disturbance dictate which species takes off? And are there weaknesses of the organism that we can better exploit for control? We'll really help resource managers when we come up with some of these answers."

One of McDonald's experiments involves collecting and identifying samples of *Armillaria* mycelium from many different sites, habitats, and hosts. He places two of the carefully catalogued isolates side-by-side on growth medium in a petri dish, charting their form and interaction. Thousands of petri dishes surround McDonald in the lab as he explains the results.

"The interaction of the two isolates as they grow tells whether or not they are compatible or incompatible," McDonald said. "If they are compatible, they are from the same genotype; if incompatible, they are from dissimilar genotypes. And, since we know the site, habitat, and host origin of each sample, we can begin to characterize which clones and species do well in which locality, or under what conditions."

"We can also challenge collected samples by growing them with known taxonomic isolates," McDonald said, "and thereby expanding our work in species identification and classification."

Plant Pathologist Neil Martin is involved in another aspect of *Armillaria* study. "Taxonomy of the species is based on the sexual form, or fruiting body of the organism," Martin said. "Producing fruiting bodies in the lab is an important step in species identification and understanding."

In the forest, *Armillaria* sends up fruiting bodies in the fall. Martin places pieces of the inoculum on growth medium in glass bottles, then simulates the temperature and light regimes typical of that season.

Martin also investigates the role of spores in *Armillaria* propagation. "We know that the organism spreads through the soil, and suspect that this is its major means of perpetuation. Reproduction through spores is not generally recognized as a major problem. . . yet," he says. And his fascination with the organism is apparent when he talks about another unsolved mystery.

"*Armillaria* glows—it gives off a soft blue light that is both observable and measurable," says Martin. This certainly requires an expenditure of energy. But why would a subterranean organism retain a light-emitting feature? Maybe to attract beetles. One can only speculate—we really have no idea why it sits down there in the dark and glows."

Harvey emphasizes the need to better understand what goes on "down there in the dark." "Our understanding of below-ground ecosystems is rudimentary at best," he said. "We need more expertise in the contributions of soil to growing healthy trees. Forest managers are eager for answers. Today's managers are receptive—they are better schooled in pathology and pest management than their predecessors, and look further at why things aren't working, at why the cut can't be sustained. They are willing to look beyond the sales aspect of a stand to the biological aspect of the entire system. And that will make the difference in successful management of forest ecosystems, both above and below the ground."

For more information on this research, contact Al Harvey, Forestry Sciences Laboratory, 1221 South Main St., Moscow, Idaho 83843, (208) 882-3557.

Preparing to harvest second-growth timber

by Dorothy Bergstrom
Pacific Northwest Station

In anticipation of the time when second-growth trees will be the primary source of timber in the western United States, researchers at the Pacific Northwest Station are searching for answers to questions that forest managers have already begun to ask about changes that second-growth harvesting will bring. Some of these questions arise primarily because new equipment and technology will be needed to harvest younger and smaller trees. Other questions are prompted by current trends in the economics of forest management and the need to better understand the relation between timber harvest and forest productivity.

One trend is toward greater utilization of wood to meet an increased demand for products. Complicating the situation is the fact that wood from second-growth trees may not be as dense or strong as that in old-growth trees, and often produces lumber or plywood with more knots and different drying characteristics. Likewise, there is a growing awareness of the relation between harvest levels and environmental considerations, such as air pollution and site productivity. Removing too much biomass may slow the growth of future forests and cause some loss of wildlife habitat, whereas an excessive amount of material left in the forest can impede wildlife movement and management activities.

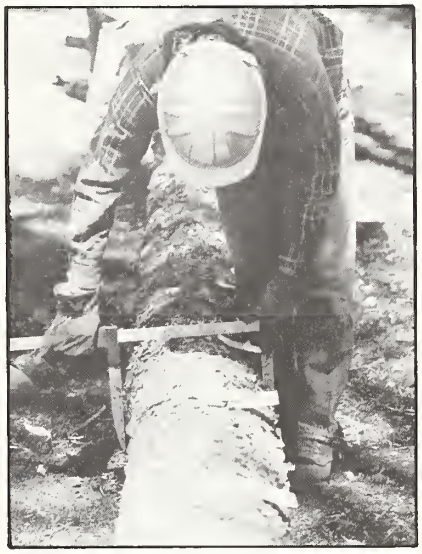
Specialized equipment for delimbing, debarking, chipping, and making hog fuel, makes whole-tree processing possible on a small landing.

As the harvest of second-growth timber increases, a new set of questions arises. According to Jim Howard, leader of the Biomass and Energy research unit, "Everything changes when we have the capability to snip off smaller trees at the ground, pick them up and move them intact. This capability marks a drastic departure from harvesting old growth trees and adds new requirements and opportunities for forest managers."

It is now possible to move whole trees to an inwoods processing site, where machines can debark, delimb, and process them for multiple products—logs, chips, and hog fuel (tops and limbs burned for energy)—that can be trucked from the forest. This capability requires changes in methods for appraising, selling, and harvesting timber. Three primary characteristics of second-growth trees are responsible for the changes: (1) smaller trees will generally have more knots but less defect and thus less breakage and cull during harvest; (2) smaller, more uniform trees and stands present greater opportunities for harvesting and utilizing entire trees; and (3) less timber volume per acre will make the use of economically efficient harvest methods more important. Where the terrain is not too steep, harvesting will be mechanized, with more of each tree ultimately leaving the forest.

One new requirement is for ways to measure volume and weight of trees. The board-foot measure that was appropriate when most of the old-growth trees were converted to lumber is not relevant to the wider variety of products made from smaller trees. Also needed are ways to measure parts of trees that have not usually been sold in the past. When old growth was harvested, a great deal of residue—branches, needles, broken boles—was left on the logging site after the boles were removed. When second growth is harvested, the wood that used to be called residue will increasingly be used for products, including energy, and forest managers will need ways of calculating its volume or weight. Forest managers have also known for some time that crowns and logs left behind provide wildlife habitat and augment soil nutrient reserves as they decay. With intensive utilization, including whole-tree harvesting, better information and methods are needed for evaluating which material should be left behind and which should be removed from a site.

To help deal with the emerging issues of harvesting second-growth timber, scientists in the Biomass and Energy Unit are taking advantage of research opportunities provided by current management situations. When they design research to provide critical information that local forest managers need to solve current problems concerning smaller trees, they plan it with the goal of also adding to the store of tools and information that have broader application to the management and utilization of second-growth timber throughout the region.



Many tree measurements are needed to produce accurate weight and volume estimators.

One such study has been completed on the Olympic National Forest. Another in south-central Oregon is in the final stages. The studies were done with the cooperation of land managers, timber operators, and public agency staffs. This cooperation has made possible work that otherwise would not have been done, or at least would have been much more difficult and costly. Although they help answer the questions of local land managers, these studies are also part of a larger plan to provide this type of information throughout the West.

"Doghair" stands in Washington

On the Olympic National Forest, forest managers needed help in their attempts to harvest dense stands of overstocked, small timber—the kind known as "doghair"—so the area could be planted with more productive stands. The stands to be replaced consisted of stagnated, 50- to 60-year-old western hemlock, Douglas-fir, and western redcedar, with density ranging from 2,000 to more than 25,000 stems per acre. Most trees were 70 to 80 feet tall; average stand diameters were less than 8 inches. Some of the stands were growing on very steep slopes. Through repeated attempts to harvest these stands, the management staff of the Quilcene Ranger District found that existing harvest methods and equipment were not adequate for the job. They also found they needed to know how to estimate the amount of woody biomass that could be marketed and how its removal would affect future tree growth.

A new harvesting system, using inwoods processing, was developed by an innovative local timber operator. This system, involving new technology and total-tree marketing, provided the opportunity to harvest the doghair stands where conventional approaches had failed. It was decided that even greater gains in efficiency could be obtained by developing processing equipment

specially designed to handle the small trees being cut. The commitment of the land manager and the timber operator resulted in a contract in which the Ranger District provided timber for testing newly developed equipment provided by the logging operator. The contract also incorporated research planned and conducted by Howard's unit, both to answer questions facing the District, and to expand knowledge about small-tree harvesting. The research was made possible with financial assistance from the Department of Energy.

Equipment purchased or developed for the harvesting and processing system included: a feller/buncher, capable of working on slopes as steep as 80 percent, that was used to cut the trees; a clam bunk forwarder, or skidder, that transported the prebunched trees to the processing site; a mobile loader for sorting and positioning trees for processing; a prototype chain-flail machine for cleaning bark and limbs from trees destined for chipping; a chipper that processed debarked trees into clean chips; and a shredder that produced hog fuel from all tree parts not converted into logs or chips. Costs and productivity of each piece of equipment and the entire processing system were determined.

Because new equipment makes possible the harvesting of second-growth ponderosa pine, forest managers need better information to meet the challenging decisions about utilizing and marketing it.

The findings were specific to the particular site, but the methods developed can be adapted to similar situations. The study accomplished the following:

- determined the costs and productivity of new equipment;
- described the wood density of small-diameter trees;
- developed biomass estimators for trees and tree parts;
- described the distribution of nutrients in trees, forest floor, and soil;
- determined the energy value of chips made from entire trees and from various tree parts;
- found that the nutrient capital in living crown material constituted a small portion of the total for the site;
- found quite a bit of dead material on the forest floor;
- found stem densities not appreciably different from those found in old-growth trees of the same species.

Lodgepole pine in southwest Oregon

The management problem on the Winema and Deschutes National Forests in south central Oregon was what to do about 300,000 acres of lodgepole pine vulnerable to infestation by the mountain pine beetle. The possibility of slowing down the infestation by harvesting trees larger than 7 inches in diameter—the preferred habitat of the insect—improved considerably after powerplants in northern California began to show interest in using the lodgepole for fuel.

One of the questions that needed study was how to estimate the biomass of standing trees so that both buyer and seller could have a basis for talking about amounts and value. Perhaps more important was the need to find out what nutrients were located in various tree components, ground cover, and soil, and what would be the effect on the nutrient capital of the pumice soils if whole-tree harvesting removed them.

Research designed and conducted in three Ranger Districts by scientists in Howard's unit is expected to produce information that will be applicable to the entire area of south-central Oregon where lodgepole pine grows on pumice soils. The information will not only assist local forest managers but will also add to the store of knowledge about harvesting second-growth trees.

The expected results will include:

- new equations for predicting the amount and distribution of woody biomass in trees and stands;
- equations developed from many measurements of sample trees to provide information buyers and sellers can use in talking about biomass products by volume or weight;
- estimates of the amount of carbon, nitrogen, sulfur, and phosphorus in all ecosystem components: boles, crowns, and roots of trees; shrubs, dead trees, and soils;
- equations that allow calculation of the loss of nutrients that will result from any level of harvest, including whole-tree harvesting;
- an index of competition based on crown width, crown length, and tree height and basal area;
- an evaluation of the effects of competition on the distribution of biomass and nutrients in trees.

Conclusion

The information from completed and future studies will be organized into computer models that display relations that have been established by research. One such model, already developed, can allocate the entire tree or stand to potential products, based on utilization standards specified by the user. For example, the product allocation model can be used to evaluate the products that result from different utilization standards for a particular stand, or to see how the same standards will produce a different mix of products when applied to different stands. Use of the model will be expanded as data for other species and geographic areas become available.

The unit is now planning a similar study of ponderosa pine on the Deschutes National Forest in central Oregon. This is another instance where research was spurred by land managers' interest in finding out the amount of biomass that might be harvested and the relation between harvest and future productivity. The approach will be similar to that used with the lodgepole pine study now nearing completion. Similar results are expected. The results will be available to support harvest decisions and will also be used in a long-term study of the effects of intensive harvesting on the productivity of second-growth ponderosa stands.

Howard says, "The goal of our research is to provide forest managers and timber operators with information that will allow them to describe and evaluate economically acceptable strategies for harvesting second-growth stands and to better understand the effect of a planned level of utilization on other resource values."

People who would like more information about the work on harvesting second-growth trees can write to the Biomas and Energy Research Unit at the Pacific Northwest Station or call (503)231-2030, (FTS 429-2030) and talk to Jim Howard, Mike Lambert, Susan Little, or Dale Waddell.

Where deer and cattle roam

by Richard Pearce, for Pacific Southwest Station

What do today's wildlife managers have in common with the game keepers of Elizabethan England? "A concern that cattle might adversely affect native deer populations," says John Kie of the Pacific Southwest Station.

"The controversy about livestock and deer goes back literally hundreds of years," Kie, a research wildlife biologist, said during a recent interview. "More recently, there has been specific concern by the California Department of Fish and Game and biologists studying the Western Sierra Nevada ranges, that cattle and deer may compete for various resources."

But not until Kie and his coworkers from the University of California at Davis, and the California Department of Fish and Game, launched their series of cooperative studies, was there any hope that the debate could be settled scientifically. Now, their ongoing investigations are giving land and wildlife managers the data they need to make rational decisions about how to maintain Sierra Nevada rangelands to the benefit of both deer and cattle.

"In the past, there simply were no guidelines for incorporating deer management objectives into the establishment of stocking rates," said Kie. "Decisions about what stocking level to use on the deers' summer range have been based solely on how cattle might reduce forage in a single area like a meadow."

Kie further noted that the few studies conducted previously failed to relate the observed effects to different levels of cattle stocking.

"The studies were not of the best design because they did not manipulate the main factor—the livestock," said Kie.

In order to provide a benchmark against which the basin-wide impact of various levels of grazing could be gauged, Kie and his colleagues have been evaluating the effects of no, moderate, and heavy cattle grazing on deer habitat and behavior over entire home ranges. There are several ways livestock could adversely affect deer. By trampling low-lying foliage, cattle could reduce or eliminate the cover fawns use for protection against predators. Excessive grazing could alter the quality or amount of food available in a particular area, forcing adult deer to expend precious energy seeking food or shelter elsewhere. The PSW cooperative studies measured these effects separately in a series of investigations over three years. Still to be determined is whether deer survival is actually threatened by such pressures, but the findings thus far have provided several clues about which of grazing's many effects are likely to have an impact on deer stamina.

Working with Kie are Eric R. Loft, John W. Menke, Montague Demment, Joy Winckel, and Emilio A. Laka of the Department of Agronomy and Range Science at UC Davis, and Ron C. Bertram of the California Department of Fish and Game.

The Forest Service provided much of the funding for both projects, with the California Department of Fish and Game supplying field workers and material.

Research on interaction between mule deer and cattle was conducted in the McCormick Creek Basin on the Stanislaus National Forest in California.

The researchers chose two study areas, both in the Stanislaus National Forest: McCormick Creek Basin, a mountain basin at about 2,500 meters, and Bell Meadow at a slightly lower elevation. The McCormick Creek Basin was divided into three pastures; one stocked at a normal rate (moderate grazing), another at a high rate (heavy grazing), and a third with no cattle. In the Bell Meadow study, a single riparian-meadow habitat was partitioned into small pastures and stocked with tame deer and cattle at four different stocking rates. In both series, the treatments were rotated yearly through the pastures.

Kie characterized the McCormick Creek studies as "broad scale," designed to study the effects of cattle on several aspects of deer behavior over a variety of habitat types. The Bell Meadow study, in contrast, was an "intensive" investigation of cattles' effects within a single habitat.

Hiding cover

Deer are most susceptible to predators during their first two months of life, and biologists have long suspected that a reduction of suitable cover caused by excessive cattle grazing may appreciably lower fawn survival. However, changes in hiding cover over an entire season at different levels of grazing has never before been measured.

In the McCormick Creek study, the researchers quantified hiding cover for fawns by recording the percent of a square grid, one meter on a side, and divided into 0.01-m^2 squares, that was obscured by vegetation or debris when observed at several points from the center of 0.01 hectare plot. Complete results were published in the Journal of Wildlife Management (vol. 51(3):655-664). The principal findings of the study? Even when no cattle were present, hiding cover declined over the course of the summer due to the maturing and weathering of vegetation. But with cattle present, the decline was accelerated.

"The natural loss of hiding cover during the course of the summer really doesn't matter," said Kie, explaining that "by the end of the summer, fawns have matured and their defense strategies have shifted more to outrunning predators." The most important time for cover, Kie said, is early in the summer "when the fawns are young they depend on hiding to escape predators."

But when cattle are present the loss of cover occurs sooner, causing a large proportion to be lost early in the season when fawns need it the most. "What's more," said Kie, "the more cattle you put in there the quicker that decline occurs."

The researchers presented their data in a graphic form with percent change of hiding cover for three different vegetation types plotted against zero, medium, and high stocking rates (Figure 1). To reduce the natural effects of weathering, only the change in cover from the beginning of the summer to mid-August was included. The resulting negative curvilinear relationship turned out to be a fairly good descriptor of what cattle can do to hiding cover in the three major deer habitats.

"A resource manager who is concerned about hiding cover for fawns can go to the chart and see that it would be unwise to stock heavier than 0.5 animal units per hectare," Kie said, commenting on the utility of the graph. "On the other hand, if there's a situation where there aren't a lot of predators around and fawn survival is good, a manager might want to stock at some other level based on some other goal."

Kie is careful to point out that his production curve is not necessarily applicable to areas outside the McCormick Creek Basin.

Habitat choices

Also under study at McCormick Creek Basin is the way deer select and use their habitats under the three different cattle stocking rates. If cattle are altering normal patterns, then the scientists might gain insight into the ways deer are affected by grazing and to what degree.

To get a handle on behavior, three types of selection were considered: first-order selection, which is the deer's choice of a physical or geographical range; second-order selection, which compares the percentage of habitat types in the home range, i.e., aspen, meadow-riparian, montane shrub, conifer, dry meadow, and sagebrush, to that of the basin as a whole; and third-order selection, which relates to how deer go about using the different habitats within the home range.

Abundant hiding cover in aspen habitat can last through September in the absence of cattle grazing.

Excessive grazing by cattle can eliminate cover for mule deer in aspen habitat by September.

In order to study habitat choices, the researchers had to be able to look at second- and third-order selection by following the movements of single deer. To do this, they outfitted each animal with a radiotransmitting collar. Its location at any given moment could then be determined by triangulation. After several days of record-taking, a map of a deer's home range (representing second-order selection) could be drawn.

Comparing the composition of the home range to that of the basin as a whole, the scientists discovered that, when no cattle were present, deer tended to select more meadow-riparian habitat than is typical for the basin. In contrast, when cattle were present, the deer selected home ranges with less meadow-riparian habitat.

Just the opposite was seen for the montane shrub habitat, located mainly on slopes surrounding the basin. With no grazing, deer showed no preferential selection of this habitat. But with moderate, and even more with heavy stocking levels, deer increased the proportion of montane shrub habitat in their home ranges.

Thus it was discovered that cattle were, for whatever reasons, altering the deer's second-order selection choices.

It was also observed that deer increased the size of their home ranges in the presence of cattle. The studies showed, too, that the cattle affected third-order selection, that is, the time deer spent in a particular habitat within the home range.

"When cattle were around, deer take in more area than they would normally," said Kie. "They spend more time in a bigger home range and use habitats differently."

With no grazing, deer favored aspen groves. With cattle present, however, the time a deer spent in the aspen habitat fell significantly.

At all stocking rates, mule deer also spent a good deal of time in the preferred meadow-riparian habitat, while avoiding sagebrush. Montane habitats were occupied with equal frequency whether cattle were present or not.

Interpreting the results, Kie said that "sagebrush is not a very useful habitat for deer in McCormick Creek Basin; it's dry, there's not a lot of grasses or forbs out there for forage, and the cover is very low." In contrast, he said that "aspen overstory provides both thermal cover, screening the sun in the daytime and holding in warmth at night, and some interception of rainfall and hail. Most importantly, it provides a good source of high quality forage."

Although no significant difference was noted in a deer's occupation of sagebrush between the heavily grazed, moderately grazed, and ungrazed lands, Kie said the trend was towards less avoidance of the sparse habitat with heavy grazing.

"All this suggests to me that as deer are being displaced from the preferred habitats they are going to the less preferred ones," Kie said. "Under conditions of no grazing in the pastures, they don't spend any time at all in the sagebrush. But they'll spend a little bit more time with moderate grazing and more time still with high grazing. It's as if they were being forced into those habitats."

The most dramatic shift in third-order selection occurred in the aspen habitat where deer spent significantly less time with moderate and heavy grazing levels.

Kie believes that cattle grazing does not appreciably affect aspen overstory but that it does take out a lot of the low-strata cover. "Once this resource is gone," he says, "the deer spend less time in the aspen habitat."

Kie does not endorse the frequently made argument that deer shun a habitat simply because cattle are present. "There are plenty of examples both today and dating back to the 1600's where people report seeing deer and cattle feeding side by side. My feeling is that the social intolerance is a lot less important than what the cattle are doing to the forage and hiding cover resources," Kie said.

Also under investigation was how cattle might affect deer activity within their home ranges. Kie suspects that an increase in energy expenditure might be one of the prices a deer must pay when cattle force it to move from preferred habitats, or to increase the size of its home range.

Cattle tend to prefer some of the same habitats deer do. They concentrate in creek bottoms and in aspen patches. But as the deer expand their home ranges, they tend to use more of the steeper slopes." Kie muses that if he were a deer, he would want a home range "that is small and one where I wouldn't have to climb up and down a hill everyday to get water, forage, and cover."

Feeding, traveling, or resting?

Additional clues about how cattle might be affecting a deer's energy expenditure can be obtained by monitoring its activity on a 24-hour basis.

Radiotransmitting collars were equipped with tip switches that changed the frequency of the emitted pulse depending on whether the deer's head was up or down. When the deer was feeding and its head was down, the collar gave off a slow pulse.

When the deer was not eating and had its head up, the pulse rate was high. To find out if a deer was moving, the researchers simply exploited the fact that the strength of a radio signal abruptly changes whenever an animal shifts its location.

Findings for 1984 and 1985 revealed that with higher stocking rates, the deer spent more time feeding and less time resting than they did when no cattle were present.

"Although the relationship was not a very tight one, we saw a distinct pattern that, as the cattle ate more and more of the forage that was available in the meadow-riparian habitat, the deer were spending more time feeding and traveling," Kie said.

The researchers also examined whether there was any difference in the way deer broke-up their activities over a 24-hour period. The biggest response they saw was in the length of the resting bouts.

"In 1984 with no grazing the average resting bout was 112 minutes," Kie said. "With moderate grazing it was 56 minutes while under heavy grazing it was 32 minutes."

A similar though less dramatic pattern was seen in 1985. That was a drought year in the Western Sierra, and forage conditions were poor. Accordingly, resting periods were much shorter. Still, there was a decline in the length of the average resting bout as a function of cattle grazing. Kie said that with no grazing in 1985, they measured an average resting bout of 36 minutes. That dropped to 33 minutes with moderate grazing and 25 minutes under heavy grazing.

"The overall trend was for deer to rest for shorter periods of time when there were a lot of cattle around," Kie said summing up both years' data.

But is a decline in resting time at the expense of increased foraging necessarily a problem for deer? To find a suitable answer to this all-important question, Kie turned to recently amended ideas about what costs an animal must pay in order to survive.

Optimal foraging theory

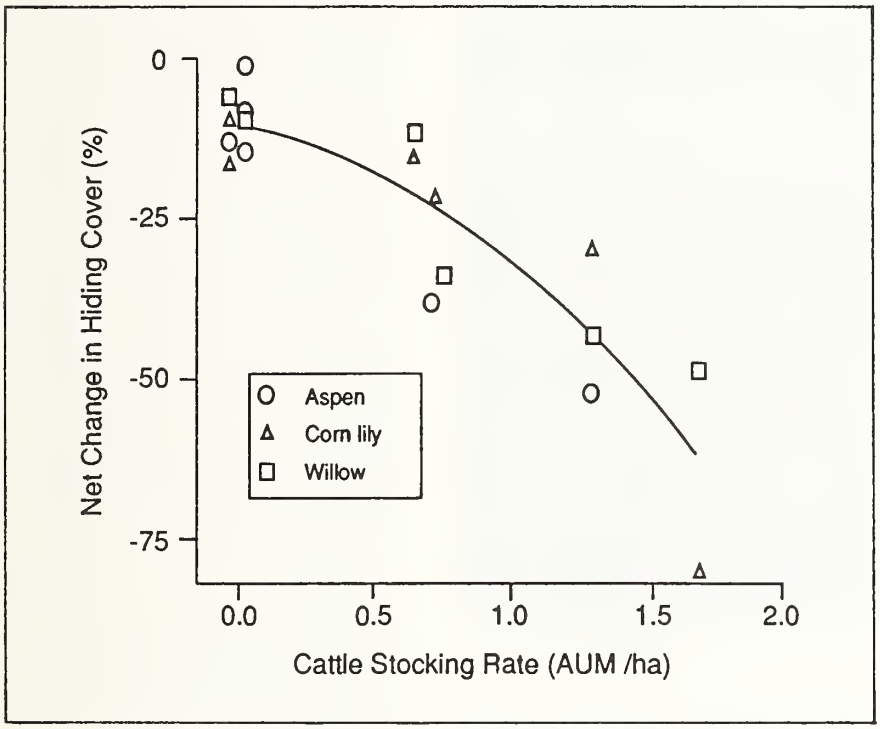
In the past, biologists have looked at animal survival largely from the standpoint of forage energetics, that is, how much energy does an animal have to expend to obtain life-sustaining nutrients? Recent work, however, has broadened this "optimal forage theory" to include, in addition to the energy costs of finding food, the costs of reproducing and avoiding predators as well.

"It doesn't do an animal any good to use a minimum amount of energy to get all of its nutrients if it's doing it in an area where there are alot of predators around," insists Kie. "In some cases the animal would be better off to spend a little more energy getting food in a different area it it's much safer from predation."

In the case of the mule deer, Kie believes it is in the animal's best interest to obtain food quickly. "Every minute a deer takes looking for food means that it is less wary of predators." Kie says he can't prove that those deer that spend more time foraging are any less likely to survive a summer than deer that spend less time foraging, but he calls it a "reasonable assumption that fits with the new developments in optimal foraging theory."

Practical implications

To help managers with their decisions about how best to stock a deer's home range with cattle, Kie hopes to derive production curves similar to the one for hiding cover to express the various response variables such as habitat selection, home range size, and resting bouts as a function of different cattle stocking rates.



"We want to have a whole family of curves so that we can make some recommendations about what cattle stocking rates ought to be to achieve a particular management goal," said Kie. "One manager might be more concerned about predation on adults than fawns, in which case it would be more appropriate to consult an activity graph to see how percent of time feeding varies with stocking rate. A different manager might be concerned that the deer's fat reserves at the end of the summer aren't high enough to sustain them through the winter. In that case, he might want to reduce the cattle stocking rate to the point that the deer have small home ranges at the bottom of the basin where forage is abundant, so that the deer don't have to spend all day going up and down hills or running around large home ranges to get their forage."

How a particular manager uses the production curves, Kie says, "will depend on what the situation is with each deer herd, and what the herd management goals are."

Bell Meadow: a study in detail

Early on in the McCormick Creek Basin study, it became apparent to the researchers that the meadow habitat was a significant one for mule deer. Accordingly, it was decided to put a single montane meadow habitat "under the microscope" to evaluate more closely how cattle affect deer behavior. For starters, they looked at feeding and rumination habits.

They divided Bell Meadow into four small pastures and stocked them at the four rates: not grazed, lightly grazed, medium grazed and heavily grazed. "There's a tremendous amount of information that's just now being analyzed," said Kie. Nevertheless, he said that the UC Davis researchers were able to conclude in a preliminary report that deer probably suffer a decline in nutrient intake with heavy cattle grazing. The investigators observed that with increased stocking rates and the associated decline in meadow biomass, there were increases both in number of bites per minute and steps per minute taken by deer.

"Instead of being able to stand in one place for a long time and taking several bites, deer were having to take just a few bites and then move on," said Kie. The findings suggest to Kie that a greater searching effort was required by deer to find the preferred plant species.

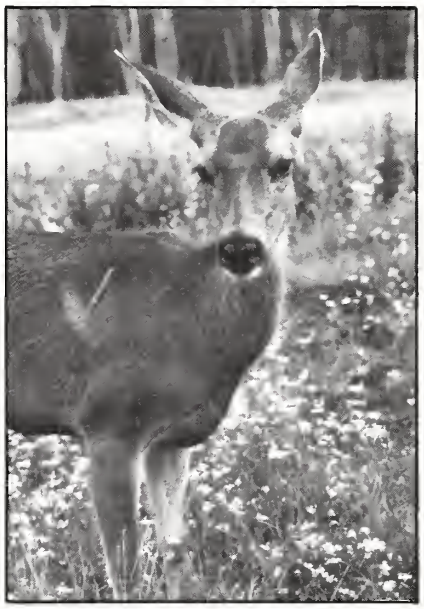
Curiously, at the highest stocking rate, total time spent feeding decreased. "That may seem contradictory to the McCormick Creek results," Kie admitted, "but Bell Meadow was a confined habitat—the deer couldn't go to other habitats like they could in McCormick Creek Basin."

Other preliminary observations with high stocking rates were that the number of boli the deer ruminated per minute decreased and the chews per bolus increased.

"To me that suggests that with heavy stocking rates the deer are taking in such poor quality forage that they have to bring up a bolus and chew it longer to break down the tough cell walls," Kie said. In McCormick Creek Basin when things got bad in the meadows, the deer could go to other habitats. They went up into the montane shrub habitats and they went to conifer habitats. There they increased their time grazing. They couldn't do that in Bell Meadow, so their only strategy was to take in lower quality forage and spend more time ruminating.

Effects not always negative

The authors of the Bell Meadow report concluded that heavy stocking rates should be avoided so that deer are not deprived of much-cherished, high quality forage. But Kie emphasizes that the consequences of cattle grazing are not always negative.



Tame deer were used to study foraging behavior in detail at Bell Meadow on the Stanislaus National Forest.

"There are some things coming out of the Bell Meadow study that suggest, at least in the short run, that some level of stock grazing may actually be beneficial to deer," Kie said. "There's a good argument, advanced by others, and which we discovered, too, that with very light stocking rates, cattle remove some of the coarser vegetation—the grasses and the sedges—and that tends to encourage the growth of forbs (broadleaf plants) that are higher in nutritional quality and preferred by deer."

Kie added, however, that it has yet to be determined precisely what level of cattle stocking improves forage conditions for deer. But as the data are analyzed further and more studies conducted, he is hopeful that this and other relationships between cattle and deer will become clearer. As a range animal that has co-existed with cattle for thousands of years, deer have proven that they have what it takes to survive. But, only with further scientific study into how deer may be ill-affected—or benefitted—by cattle, will wildlife managers be able to ensure their continued existence well into the future.

For additional information, contact John G. Kie, Forestry Sciences Laboratory, 2081 E. Sierra Avenue, Fresno, California 93710, (209) 487-5589.

Help for determining carrying capacity

by Rick Fletcher
Rocky Mountain Station

The most extensive area of grassland west of the Rocky Mountains is the semi-deserts of New Mexico, Arizona, and northern Mexico. Here, wide horizons of grasses such as blue grama, alkali sacaton, and Indian ricegrass unite with mesquite, acacia, and a variety of cacti and other arid land plants for as far as the eye can see.

Rangeland in this region is an important resource. Not only does it provide forage for domestic livestock, its primary economic value, it also offers wildlife habitat, water, and recreation resources. And, as open space, it provides a much-needed esthetic buffer against spreading urban pressures. But much of the land being used for grazing is in poor condition because of overuse. In fact, some areas have been continuously grazed year-round for decades.

One people that rely heavily on grazing is the Southwest Indian tribes. Realizing that many of their ranges were in less than optimal condition, and wanting to make improvements, in 1986 the Albuquerque (New Mexico) Office of the Pueblo Council, Bureau of Indian Affairs approached the Rocky Mountain Station with a request—develop a guidebook for estimating livestock carrying capacity on semi-desert Indian reservation rangelands in the Southwest.

Southwest rangelands are most valuable for livestock grazing.

So, working closely with the Bureau of Land Management and the Soil Conservation Service, scientists at the Station's Forestry Sciences Lab in Albuquerque set out to do just that. Today, that handbook is completed, and applies not only to Indian reservation ranges, but ranges throughout most of the Southwest.

The objectives of the handbook, based on operating procedures currently used by the U.S. Forest Service, Bureau of Land Management, and the Soil Conservation Service, are to:

1) outline range inventory procedures that provide data with which to plan range management activities;

2) provide a rational basis for making an initial estimate of livestock carrying capacity; and

3) outline a step-by-step method for evaluating range response to management procedures currently being used. This includes guidelines for adjusting livestock numbers as the trend of a specific range condition becomes apparent over time.

This overgrazed range is typical of many areas in the Southwest.

Mapping

Good range management is greatly dependent upon accurate, up-to-date range maps. The booklet explains that "depending on the size and complexity of a range unit, maps may be drawn directly on USGS and topographic sheets, orthophoto quads, or stereoptically on the most recent aerial photos". The goal is to map vegetation to an intensity of 40 acres, or smaller if an area is especially productive, or if it represents some particular problem (e.g. an area of poisonous plants).

An accurate vegetation map, in combination with a soils map, is a basic management tool for planning and management of a range. Other range and vegetation mapping strategies are detailed, such as capability classification—which rangelands should or should not be grazed (i.e. no capacity, potential capacity, full capacity for grazing); seasonal and topographical considerations; and soil compaction.

Sampling and analysis

Because a thorough understanding and objective evaluation of range vegetation is essential to preparing a realistic estimate of livestock carrying capacity on a range unit, much of the guide is devoted to vegetation sampling and analysis.

Stratification, plant community structure analysis, forage production estimates, utilization estimates, and production utilization surveys are all discussed.

The health or vigor of range plants, their composition and density, age or size class, and production are important in computing carrying capacities. These factors may vary substantially within short distances. Techniques to use range transects are described in the book, and will help land managers and users arrive at meaningful production and utilization averages.

Carrying capacity

Finally, and the bottom line, techniques for determining actual carrying capacity are detailed.

Carrying capacity is the long-term ability of a range unit to support grazing without materially increasing soil erosion or otherwise harming the natural plant cover. Especially on the semi-arid ranges of the Southwest, it can vary widely from year to year, depending on rainfall amount, distribution, and intensity.

Most key forage plants in the Southwest tolerate light to moderate grazing without serious long-term effects. In fact, the growth of some species appears to be stimuated by grazing. However, beyond a certain level of use, any species can be adversely affected by grazing.

A carrying capacity figure for long-term use, if based on a single year's forage production or range performance, can be quite misleading, unless the growing season in question happens to be near average in rainfall. Thus the initial carrying capacity estimate must be adjusted up or down in successive years as range performance data accumulate. The longer the recording period, the nearer the "true" level of stocking can be approximated.

Though there are several methods for establishing carrying capacity, "historical basis" and "allowable use" are considered two of the most reliable, and are outlined in the guidebook.

Historical basis

Most southwestern ranges have been grazed by domestic livestock for a long time, some for two centuries. One method of obtaining the best records possible of the prior grazing loads on a range unit is by consulting ranchers, oldtimers, and others who may have specific knowledge of the area. Related data sources are past brand inspection and shipping records.

Allowable use

Allowable use is the level of grazing utilization that can be permitted on an area when all influencing factors are considered. This method determines carrying capacity by adjusting stock numbers up or down to attain an "allowable use" for the range unit as a whole. The book discusses all related factors such as key forage plants, soil stability and range condition trends, topography, water, class of livestock, season of use, etc.

The guidebook contains a number of forms and tables, along with detailed instructions, to assist users in arriving at an accurate carrying capacity estimate. Two computer diskettes are also included containing 1) COSAM—a program that computes vegetation parameters that are being addressed, and 2) GUDSAM—which computes forage production for a given area. Both programs use raw field data to produce final calculations for estimating carrying capacity.

Measuring forage production.

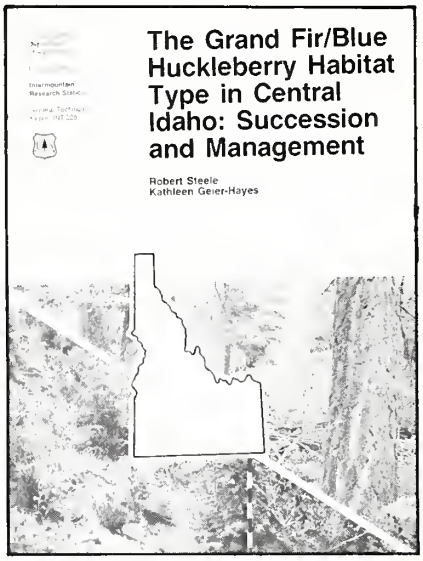
Techniques described in this guidebook are supplemented by technical literature particularly appropriate to southwestern range problems. While providing step-by-step instructions for particular analysis procedures, it should be used as a supplement to the rancher's and resource professional's own field experiences, not as a substitute for them.

If you would like more information about this guidebook, or the research described in it, contact Project Leader Earl Aldon, Forestry Sciences Laboratory, 2205 Columbia, S.E., Albuquerque, New Mexico 87106, (505) 766-2384, FTS 474-2384.

New from research

Classification of seral plant communities

Habitat type classifications focus on the environmental (site) differences affecting vegetation. While providing a logical framework for studying succession, they typically offer no classification of seral communities. But a new Intermountain Research Station General Technical Report explores the changes in vegetation and related resource values occurring over time in one forest environment. *The Grand Fir/blue Huckleberry Habitat Type in Central Idaho: Succession and Management*, General Technical Report INT-228, presents a classification of seral vegetation designed for general field use. The successional classification system is based on 92 sampled stands, and includes 21 potential tree layer types, 28 shrub layer types, and 36 herbaceous layer types categorized by a taxonomic classification.



Within the system, the relative position of a classified stand can help predict its successional pathway. Resource managers will find it useful that some types of seral vegetation are strongly related to a specific disturbance, while other types develop mainly through uninterrupted succession. These cause-and-effect relationships are presented in various ways in sections dealing with classification as well as with management implications.

The classification approach developed in the report recognizes the individual nature of specific sites in terms of existing and potential plant species composition. It also recognizes that land managers need site-specific guidelines for intensive management purposes. The somewhat independent nature of succession between the tree, shrub, and herbaceous layers is treated separately. The report indicates some interrelationships of site treatment, planted tree survival, competing vegetation, and pocket gopher populations. And most important, it provides a common framework for communication among various disciplines involved in site management.

Timber harvest has little effect on nutrient output

The chemical output from high-elevation, snow-zone watersheds on the eastern slope of the Cascade Range in Washington is not particularly sensitive to timber harvest. This was the conclusion of scientists who examined chemical output, climatic change, and turbidity and sediment production in a main watershed, four subwatersheds, and a control watershed near Wenatchee, Washington. Stream measurements were made from April to October for 3 years before and 3 years after logging by skyline and helicopter systems.

Air and water temperatures generally increased as more of the site was exposed. Stream turbidity and sediment production increased during road construction but declined to background levels within 2 years.

The mechanisms of nutrient losses are complicated and influenced by depressed or excessive precipitation. The authors state that clearcutting only portions of watersheds apparently reduced the harvest impact on all nutrient output. They believe that logging methods and cutting percentages were adequate to protect the water resource.

Copies of *Changes in Water Quality and Climate After Forest Harvest in Central Washington State*, Research Paper PNW -388, are available from the Pacific Northwest Station.

Results of spacing after 25 years

A new report from the Pacific Northwest Station provides a synthesis and an evaluation of earlier progress reports of spacing trials in Douglas-fir, western hemlock, and western redcedar at the University of Columbia Research Forest in the Fraser River Valley of British Columbia. It should help managers choose optimum spacings.

Five spacing trials, covering a range of plantation spacings from 0.9 to 4.6 m, were established from 1957 to 1967 on a very productive site to assess the effects of spacing on tree and stand development. The report also includes a summary of the designs and the periods of evaluation.

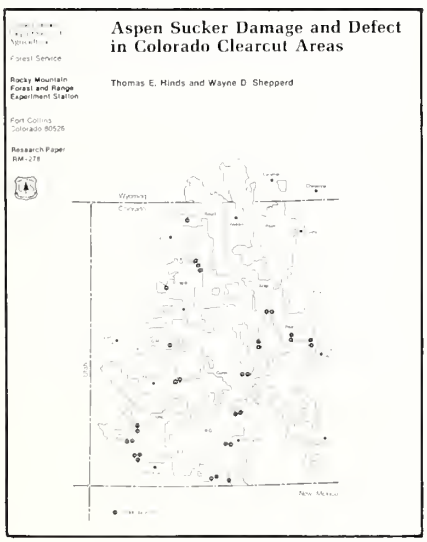
Results suggest that choice of initial spacing is one of the most important decisions made by managers. In economic and biological terms, the 3.7- and 4.6-m spacings appear to be near optimum for most regimes for producing lumber. Combined with pruning, the same spacings should be optimum for producing clear lumber and veneer. The 0.9- and 1.8-m spacings produce maximum biomass.

Spacing trees more widely between rows than within rows (rectangular spacing) can reduce planting and tending costs and facilitate uniform spacing within the first thinning. Pruning of widely spaced trees to enhance the quality of the lower bole is strongly recommended.

Write the Pacific Northwest Station for copies of *Development Over 25 Years of Douglas-fir, Western Hemlock, and Western Redcedar Planted at Various Spacings on a Very Good Site in British Columbia*, Research Paper PNW-381.

Aspen damage from clearcutting

Substantial acreages of aspen in the Rocky Mountains are being regenerated by clearcutting. Resulting suckers will develop under different circumstances and ecological conditions than did their parent stands. Young stands of suckers are easily damaged by hail, snow, frost, insects, diseases, browsing, and branch breakage—all of which help contribute to decreased growth, internal defect, and mortality.



Recent studies by scientists at the Rocky Mountain Station suggest that suckers produced following clearcutting may be similar in quality to natural stands at comparable ages. Aspen suckers from 1 to 19 years old were studied in 32 clones in Colorado. The highest frequency of damage was caused by disease, followed by dead terminal leaders, insects, broken branches, wetwood, trunk wounds, frost, basal wounds, browsing, hail, snowbreak, poor form, and root wounds. Researchers are quick to point out that the quality of suckers can be more fully assessed closer to maturity.

Additional details on this research are available in *Aspen Sucker Damage and Defect in Colorado Clearcut Areas*, Research Paper RM-278. The Rocky Mountain Station has copies.

Computer program analyzes channel cross sections

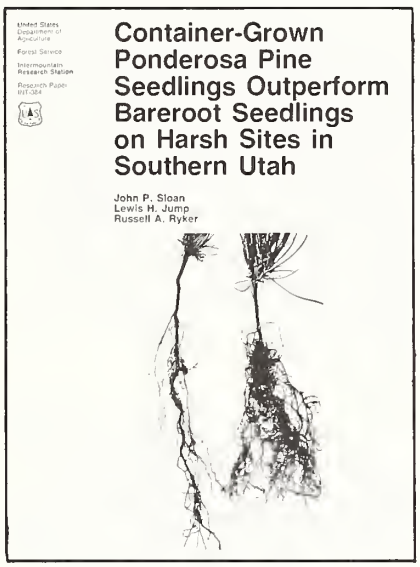
Research Note PSW-396 describes DEBRIS, a new computer program for analyzing channel cross sections. Written in FORTRAN 77, DEBRIS is a menu-driven, interactive program for recording and plotting survey data and for computing hydraulic variables and depths of scour and fill. By using menus, operators do not need to know any programming language. The five routines are: entering data, plotting, scour and fill, hydraulic variables, and computing x-y coordinates.

DEBRIS can be used on any Data General MV series computer using the AOS/VS operating system. For more information, request the above Research Note, *DEBRIS: A Computer Program for Analyzing Channel Cross Sections*, from the Pacific Southwest Experiment Station.

Improving reforestation on harsh sites

Container-grown Ponderosa Pine Seedlings Outperform Bareroot Seedlings on Harsh Sites in Southern Utah presents the results of a field comparison of ponderosa pine plantings on the Dixie National Forest after five growing seasons. Results on five sites vary from little difference in performance on the best sites, to significant differences on the harshest sites, providing resources managers with suggestions for better success in reforestation.

The low levels of available soil moisture during the spring planting season make reforestation a challenging job. Replanting has often been necessary, costly, and not always successful. But until this study was initiated, only bareroot seedlings had been planted. The trial of container-grown stock was based on prior North American studies to improve survival and tree growth. After five growing seasons, survival averaged 90 percent for all containerized grown seedlings and 79 percent for bareroot stock.



The report includes a summary of other field tests comparing bareroot and container-grown seedlings of North American conifers. For a copy, request Intermountain Research Station Research Paper INT-384.

Use of home range by mountain lions

A Research Note recently issued by the Pacific Southwest Experiment Station carries the preliminary results of studies by Dr. Donald Neal and George Steger, both of the Station's Forestry Sciences Laboratory in Fresno, and Ronald Bertram of the California Dept. of Fish and Game. Their study seeks to evaluate the relationship between mountain lions and the much-depleted North Kings deer herd in the Sierra.

In an area on the west slope of the central Sierra Nevada in California, scientists attached radio collars to 19 mountain lions and monitored them daily. Results indicate a density of adult mountain lions of one per 33.3 km^2, and of adults and kittens of one per 20.9 km^2. Their preliminary results, indicating a high mountain lion:deer ratio, suggest that mountain lions could be preventing the deer herd from recovering.

To learn more, contact PSW Station and request Research Note PSW-392, *Mountain Lions: Preliminary Findings on Home-Range Use and Density in the Central Sierra Nevada.*

Is pruning financially feasible?

Will the increase in value of products justify the investment in pruning the lower limbs from coast Douglas-fir? It all depends on the costs of pruning, interest rates, and the price premium for clear wood.

Researchers at the Pacific Northwest Station provide explanations and a computer program to help managers calculate the possible advantages from pruning. A spreadsheet program, based on data from an actual mill study that compared the lumber recovery from unpruned Douglas-fir logs and logs from trees pruned 34 years earlier, was developed to simulate the increase in grade recovery and financial return after pruning.

(The product recovery study was the subject of a feature story in *Forestry Research West*, March 1986, "How About Pruning Douglas-Fir?" The pruned logs produced more clear products of higher value than did unpruned logs. But whether the increase in value was enough to offset the cost of pruning and still return a profit has to be calculated on the basis of costs and expected returns.)

Results of the analysis show that a 5-year difference in the time of pruning can make a substantial difference in financial return. The earlier pruning is done, the better. The number of years between pruning and harvest that will give the best return depends on the site, interest rate, and whether trees were fertilized.

For help in drawing some conclusions about the financial feasibility of pruning coast Douglas-fir, ask for two publications from the Pacific Northwest Station: *Financial Analysis of Pruning Coast Douglas-fir*, Research Paper PNW-390, and *PRUNE-SIM Users Guide*, General Technical Report PNW-209.

Silviculture practices for Black Hills ponderosa pine

A new report from the Rocky Mountain Station offers guidelines that will help forest managers and silviculturists develop even- and uneven-aged cutting methods for ponderosa pine in the Black Hills of South Dakota and Wyoming.

Guidelines cover damaging agents, cutting history, even- and uneven-aged cutting methods, managed stands, costs of sale administration and logging, multiple use silviculture, and comparisons of cutting methods.

Described cutting methods are designed to maintain water quality, improve wildlife habitat, enhance recreation opportunities, and provide wood products.

For your copy of *Silvicultural Systems, Cutting Methods, and Cultural Practices for Black Hills Ponderosa Pine*, General Technical Report RM-139, write the Rocky Mountain Station.

Predicting species coverage in western Montana—FORSUM to the rescue

A new computer model will help forest managers predict response of forest vegetation to silvicultural treatments and wildfire. FORSUM (a FORest SUccessional Model) allows evaluation of the effects of alternative treatments, so that treatments yielding plant communities that best meet management objectives can be used. FORSUM predicts changes over time in canopy cover for 74 major species of trees, shrubs, and herbs in four habitat types common to western Montana. The model is based on an analysis of 774 stands, including some pared treated and untreated stands. Plant species establishment after a disturbance is based on regenerative strategies; then subsequent changes in cover for each species are modeled using regression equations. In a validation of FORSUM, species cover was predicted accurately 74 percent of the time.

FORSUM is currently available for use in Perkin-Elmer and Data General minicomputer systems and UNIVAC mainframe computers. It is designed so additional habitat types can be added later.

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

Research Note
INT-376

Forest Succession in Western Montana—a Computer Model Designed for Resource Managers

Robert E. Keane II[1]

ABSTRACT

A quantitative computer model of succession (FORSUM) has been developed for use by land managers in predicting response of forest vegetation to silvicultural treatments and wildfire. FORSUM allows evaluation of the effects of alternative treatments. The model predicts temporal changes in canopy cover for major species in four habitat types common to western Montana. Species establishment is based on regenerative strategies; then subsequent changes in cover for each species are modeled using regression equations. FORSUM also contains an easy-to-use, interactive data input routine with error checking capability and two skill levels. Output is offered in both tabular and graphic format. In a validation of FORSUM, species cover was predicted accurately 74 percent of the time. Accuracy ranged from 69 percent to 78 percent. The computer code consists of 21 subroutines and was written in FORTRAN 77. It can be modified to incorporate additional habitat types with minimal effort.

KEYWORDS: pathway model, regression, interactive program, vegetal response, succession

Predicting the composition of plant communities that arise after different silvicultural treatments or wildfire plays an important role in forest management. Because successional community composition is strongly influenced by the composition of the predisturbance vegetation and by type and intensity of disturbance, managers can manipulate successional trends to meet management objectives by selecting different silvicultural treatments (Arno and others 1985). But choosing the best treatment to meet management objectives can sometimes be difficult because there are few quantitative methods available to predict postdisturbance plant coverages. Successional classification systems such as Arno and others (1985) and Steele (1984) relate successional trends to wildfire and site treatment but yield only qualitative predictions. To overcome this problem, a study was conducted to quantify coverage response to various disturbances and then develop a computer model for predicting succession in four habitat types commonly found in west-central Montana. This model, called FORSUM (a **FO**Rest **SU**ccession Model), is currently available for use by land managers. The purpose of this paper is to describe the assumptions and operations of FORSUM as well as present an evaluation of the accuracy of the model.

FORSUM is based on the classification system of Arno and others (1985). In this classification system, site characteristics, predisturbance plant composition, and type and severity of treatment define major successional pathways within a habitat type phase. Plant species establishment after a disturbance is based on regenerative strategies. Subsequent growth in cover is projected using regression equations. FORSUM predicts plant coverage for 74 species of trees, shrubs, and herbs. The model is based on an analysis of 774 actual stands, including some paired treated and untreated stands. Because all data were collected within the study area defined in figure 1, it is strongly recommended that use of FORSUM not be extrapolated to areas outside these boundaries.

The model predicts succession for seven phases in the following Montana habitat types (Pfister and others 1977):

1. *Pseudotsuga menziesii/ Physocarpus malvaceus* (PSME/PHMA)
2. *Pseudotsuga menziesii/ Vaccinium globulare* (PSME/VAGL)
3. *Abies lasiocarpa/Xerophyllum tenax* (ABLA/XETE)
4. *Abies lasiocarpa/Menziesia ferruginea* (ABLA/MEFE)

These habitat types comprise more than half the forested landscape in west-central Montana. There are four treatment types represented in the model: (1) stand-replacing

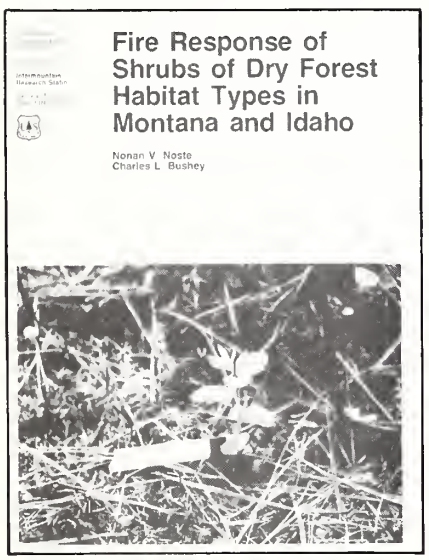
[1]Quantitative ecologist with Systems for Environmental Management, P.O. Box 8868, Missoula, MT.

An Intermountain Research Station publication describes the assumptions and operations of FORSUM as well as presenting an evaluation of the accuracy of the model.

Request *Forest Succession in Western Montana—a Computer Model Designed for Resource Managers*, Research Note INT-376.

Shrub information for fire management

The shrub component of a stand can be enhanced or depleted by prescribed fire if managers understand the biology of the shrub species. Prescription goals might be to increase shrub availability for wildlife browse or to reduce shrub abundance to favor trees.



But foresters responsible for planning fire management and specifying burn objectives are often more familiar with the effect of fire on trees than on shrubs. A recent Intermountain Research Station General Technical Report supplies information that will help in designing effective prescribed fire treatments for shrub manipulation.

Fire Response of Shrubs of Dry Forest Habitat Types in Montana and Idaho, General Technical Report INT-239, contains summary information on the biological attributes and response to fire for 20 shrub species. It includes information on the regeneration capabilities, response to fire, and utilization of shrub species important or common to the dry forest sites. Response to fire is classified by reproductive strategies and how the species persists in the stand. Utility of the species for browsing by livestock and wildlife is included.

Census time for western trout

There are significant interregional differences between the density and biomass of trout in the western United States, according to the results of a study recently published by the Intermountain Research Station. Generally, trout density was highest in the Rocky Mountains, while trout biomass was greatest in the Sierra Nevada and Upper Gila Mountain ecoregions. Density and biomass of brown trout were significantly greater than those of brook, bull, cutthroat, and rainbow trout. And, streams occupied by multiple species of trout had densities and biomasses that were not significantly different from those streams occupied by single species.

Density and Biomass of Trout and Char in Western Streams, General Technical Report INT-241, reports the first compilation of trout population characteristics in the western United States. It present information from a variety of stream habitats representative of western ecosystems, for use by biologists and aquatic resource managers evaluating their particular aquatic habitats. The data will assist land-use planning and management requirements concerning fish populations as outlined under Federal law, and will serve as an aid for considering fish population needs.

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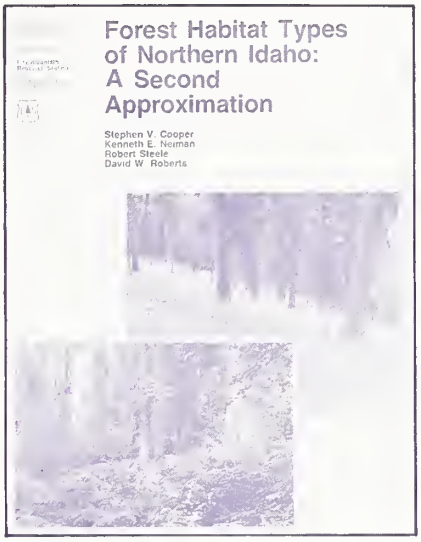
Round two for northern Idaho habitat types

The widespread use of habitat type approaches to forest site classification has emphasized the need for management of ecosystems rather than individual resources. Today's foresters want site classifications that provide greater detail than earlier versions in terms of management utility and multiresource application. While early habitat type classifications serve as models, they can be refined to better reflect the full range and diversity of forest environments.



Forest Habitat Types of Northern Idaho: a Second Approximation presents a land classification system for that part of Idaho from the Salmon River north to the United States-Canada border. It refines the Daubenmires' widely used 1968 classification by developing a system based on reconnaissance and detailed sampling of approximately 1,100 stands. The Daubenmire habitat type concept is used to construct a hierarchial taxonomic classification of forest sites. Eight climax series, 49 habitat types, and 60 additional phases of habitat types are defined. A dichotomous key, based on indicator species used in development of the classification, is provided for field identification of the syntaxonomic units.

Request Intermountain Research Station General Technical Report INT-236.

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